Integrated Systems Analysis and Sustainable Development

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Abstract: The paper presents integrated systems analysis (ISA) as a "tool" for modelling and for the development of decision support systems (DSS). ISA enhances understanding of the complex relationships between different disciplines in the form of inputs → transformations → outputs and also facilitates an understanding of the term sustainable development. Further, the paper presents a definition and model of ISA and discusses performance of component systems or distribution patterns in relation to a time horizon. Some component systems create constraints and impact other component systems which over time undergo transformations such as self-organisation and self-regulation. Some component systems may adopt a distribution pattern as an output. Therefore, behaviour of component systems or distribution patterns may be defined as growth, decline, stable conditions or oscillation. On the basis of the above it is possible to apply an integration of disciplines by integrated analysis of relevant component systems. Further, the adoption of this approach promotes the conclusion that sustainable development may be modelled, managed and maintained by control of the relevant component systems. In general terms component systems may be classified as those which impact on others, and those which are impacted on by other component systems. Population growth and all human activities generate component systems which, clearly, impact on component systems of the environment. General examples of ISA are Agenda 21, climatic changes and impact of population on the environment. Specific examples of ISA may be considered to be analyses which justify the need to, eg: improve water quality; reduce soil salinity; or define the distribution pattern of population in a country to improve strategic planning of cities. ISA may be considered as a "tool" for integrated modelling and assessment (IMA) which provides inputs to DSS for appropriate management of sustainable development/sustainable systems.

Keywords: Sustainable development; Systems analysis; Modelling; Performance of systems; Distribution patterns; DSS

1. INTRODUCTION

Since the Brutndtland report [WCED, 1987] and later Earth Summit [UNCED, 1993] the scientific community has been engaged in an attempt to explain the meaning of sustainable development. The difficulties of understanding this term are related to the lack of an appropriate and accepted methodology, which could be applied to analysed complex problems. But these difficulties also relate to the complexity of natural systems which are impacted by human activities, and this complexity is much greater than any available computer model. Any natural system consists of chemical elements and/or living organisms, which for the purpose of systems analysis are called component systems. Component systems are characterised by certain behaviour which depend on the function performed by such component systems within the particular system and other related systems. The difficulties and complexity of the issue are related to the fact that the same component system performs different functions in different systems. A component system could also be growth of a city (or cities) towns or rural area presented by curves in the population distribution pattern within a country [Soroczynski, 1999, 2001]. Other examples of complexity are: i) carbon dioxide is absorbed by plants but generated during the process of burning; ii) water is essential for live of organisms but availability depends on geographical location, climatic conditions, seasonal variation and water cycle; iii) oxygen is essential to the life of worm blooded organisms, is used during burning, is generated by plants and is required to maintain aerobic processes in rivers.

On the basis of the above it is clear that understanding the behaviour of component systems, in respect to related systems, is the crucial issue of sustainable development. In general terms component systems within an analysed system may be classified as those which impact on others, and those which are impacted on by other component systems. Population growth and all human activities generate component systems which, clearly, impact on component systems of the environment. If this argument is accepted all other component systems, except population growth and all human activities, should be maintained in a sustainable form. Further, Agenda 21 [UNCED, 1993] recommended integration of disciplines, but integration of disciplines is only possible by integrating the output of component systems and understanding behaviour of component systems in relation to analysed and other systems. On the basis of the above, it is postulated that sustainable development/sustainable systems may be analysed and performance measured by integrated systems analysis (ISA) of component systems. In addition, ISA links population growth with population distribution pattern and time horizons.

General examples of ISA are Agenda 21, climatic changes and impact of population on the environment [UNCED, 1993; IPCC, 1996; UN, 1995]. Specific application of ISA is much more complex and requires elaboration. The basic model of systems was developed by Meta Systems Inc. [1975, p. 29]. This basic model has been updated to be consistent with the adopted terminology for the definition of integrated systems analyses, and process control and is presented in Figure 1. This figure illustrates component systems that may have inputs from human activities or other inputs which cannot be controlled. Inputs affect the interaction of component systems. Outputs may be affected inputs. It is also possible to manipulate outputs by human activities. General and specific models of ISA for assessment of sustainable development/sustainable systems, except for population growth and all human activities, are presented in Figure 2.

The objective of this paper is to present ISA on the basis of behaviour and performance or distribution patterns of integrated output of component systems. In this approach scientific or expert interpretations become crucial elements of analysis and DDS. Further strategies and actions are to be developed and should be monitored in order to maintain sustainable systems of natural resources.

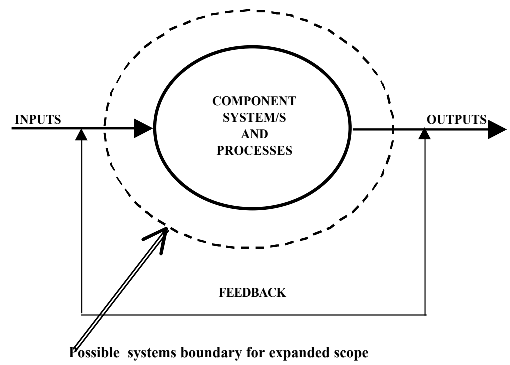

Figure 1. Basic model of component systems and process control.

2. INTEGRATED SYSTEMS ANALYSIS

2.1 Background

Miser and Quade [1985 and 1988] developed a handbook of systems analysis and on this basis Shaw et al. [1992] researched the system approach in relation to sustainable development. In this report the concept of sub-systems was used and this issue needs elaboration. If the following examples are considered say; example 1- population, environment and climate; example 2- agriculture, environment and water quality, example 3- population, land and water resources and water quality; the question arises which systems need to be considered as sub-systems of other systems? In relation to the concept of sustainable development, the concept of sub-systems needs to be replaced by the concept of component systems.

Later research [Bossel, 1998, p. 35] assumed that a system is composed of *systems elements* connected in a characteristic system structure and the configuration of system elements allows it to perform specific systems functions in its environment. It should be noted that this approach needs correction as within the same systems different component systems behave in the different way eg. towns and rural areas as component systems of population distribution pattern and other examples above.

The above examples illustrate that all systems are composed of component systems only and, as such,

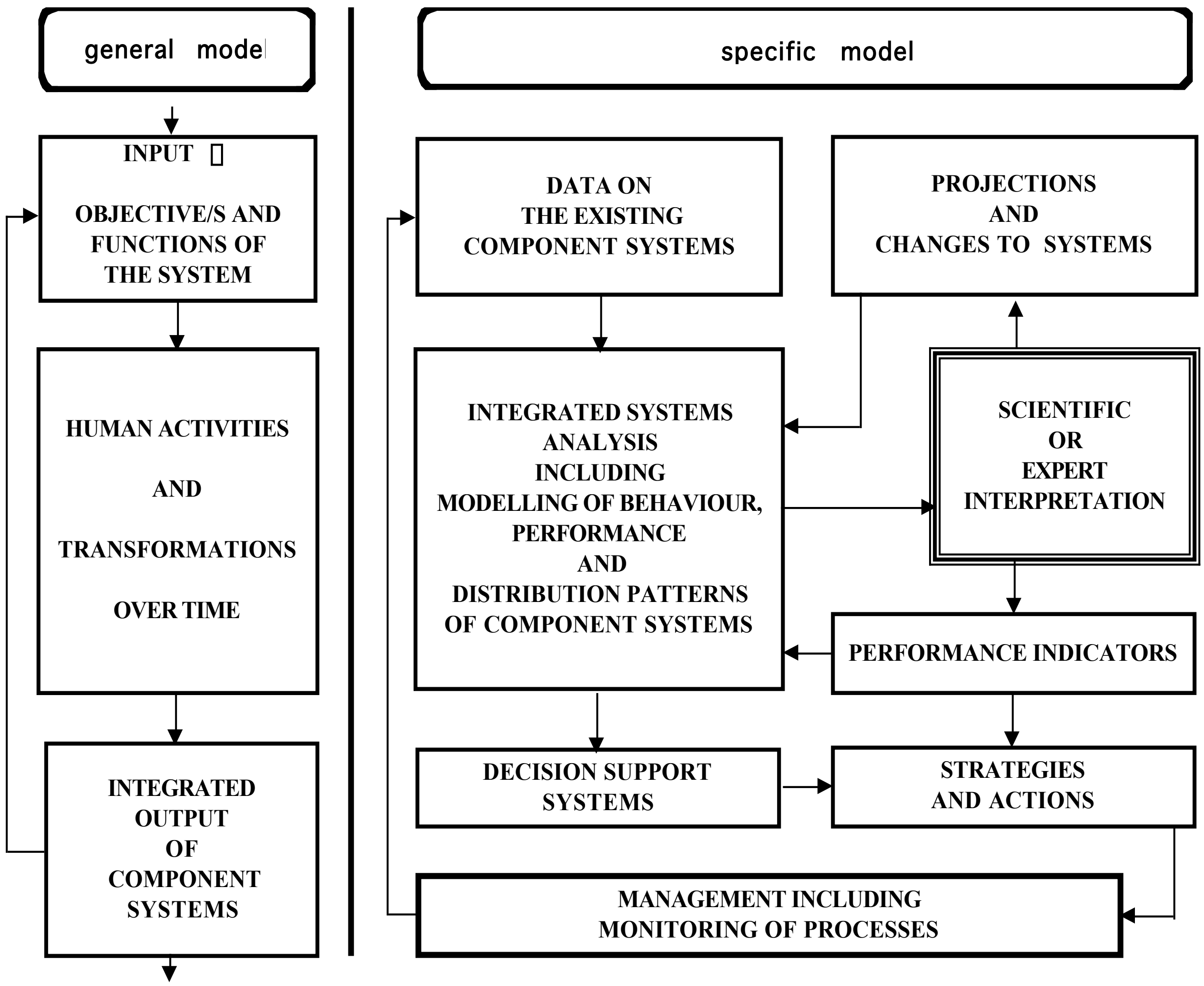

Figure 2. General and specific models of ISA for assessment of sustainable development/sustainable systems.

must be considered as integrated parts of a whole system. Bossel [1998, p. 67] has summarised his research in the following way:

Our world consists of dynamic [component] (word *component* has been added by the autho*r) systems that interact with each other and cause each other to change.*

This approach needs further deliberation in relation to the definition and behaviour and performance of component systems.

2.2 Definition of ISA

Soroczynski [1999 and 2000] researched the concept of integrated systems analysis (ISA) in relation to general population distribution patterns and land and water systems. Further consideration of sustainable development and sustainable systems requires that the previously adopted definition be revised again. The author now proposes the following definition: *Integrated systems analysis (ISA) can be defined as application of the scientific method for examination of complex problems impacted by interdisciplinary component systems. ISA, therefore, is a combination of theories and techniques for studying, describing and making predictions, on the basis of inputs transformations outputs of 'component systems' or 'components', which may be presented in the format of differing scenarios. Such analyses of component systems may need to be conducted individually, or may need to be integrated, and may also need to consider classification of systems, adopted time horizons, and uncertain conditions, where applicable. Further, these analyses may be conducted using* *advanced mathematical or statistical procedures. However, the essence of ISA is not found in a collection of quantitative techniques, but rather in a broad integrated output of scenarios needed for the development of appropriate decision support systems and strategies relevant to the maintenance of sustainable systems*. To clarify this concept, the terms 'component system' has been explained above but 'component', as a term, requires elaboration and explanation. A 'component system' must be understood to be an integral part of other related component systems. A 'component' is a factor which influences decision making and is related to human activities eg; economic analysis.

2.3 Behaviour/Performance and Distribution Patterns of Component Systems

Behaviour/performance and distribution patterns of component systems need to be considered, where applicable, in relation to sustainable systems. The time factor, past performance and future outputs of changes are the forces which impact on component systems. Behaviour/ performance of component systems or distribution patterns need to be considered over time during which they may indicate growth, a decline, stable conditions or oscillation, see Figure 3.

On the basis of the above it is possible to apply an integration of disciplines by integrated analysis of output of relevant component systems. Further, the adoption of this approach promotes the conclusion that sustainable development may be modelled, managed and maintained by control of the relevant component systems. In general terms component systems may be classified as those which impact on others, and those which are impacted on by other component systems. Some component systems create constraints and impact other component systems which over time undergo transformations such as self-organisation and self-regulation. Some component systems may adopt a distribution pattern as an output. As stated above, population growth and all human activities generate component systems which, clearly, impact on component systems of the environment.

ISA has been applied to population growth [Soroczynski, 1999, 2001]. In this research ISA considers population growth on a national level, and scenarios for distribution of population within a country, under uncertain conditions. Scenarios were then developed on the basis of current trends, appropriate selection of time horizons and the fact that people live in cities or mega-cities, towns and rural areas. Clearly as the reality is more complicated than any general model and a current output cannot provide all answers, such outputs need to be periodically up-dated.

2.4 Time Horizons

Various time horizons are adopted by different scientific disciplines for management of essential resources related to their areas of responsibilities. These differences and discrepancies could be of great concern in relation to current practices for management of natural resources. The level of confidence for predictions of future events from different scientific disciplines must be examined and understood in order to improve management of natural resources. Such time horizons have been defined and justified for climatic changes [IPCC, 1996] and population growth only [Lutz, 1996], and currently have been adopted as 100 years. On the bases of current practices adopted time horizons are defined separately for each of the following systems. These time horizons have been defined and utilised for each of the following systems with the exception of the environment:

- population growth
- climatic conditions
- water resources planning and
- economic analyses.

Frederiksen et al. [1994] commented that a selected time horizon should reflect time at least equal to the useful life of the largest commitments. However, Frederiksen did not provide practical justification for the selection of a time horizon.

A definition of time horizons needs to be consistent with human perception of the future and also related to a demographic understanding of the future. It must also be related to relevant disciplines in order to maintain sustainable systems. Soroczynski [1999] postulated that:

'Time horizons' may be understood to be mobile points or dates in time which need to be revised periodically and extended into the future. Such periodical revisions or extensions should be based on new databases for a population growth component system.

Time horizon has been researched for population growth in relation to growth of cities [Soroczynski, 1999, 2001] and this research is presented below as an example. Demographers have been concerned with inaccuracy and uncertainty of world population projections. The world population has been projected subject to uncertainties related to the next period of 50-100 years. On the basis of Lutz's [1996] deliberations the following accuracies have been considered; i) projections for the current period up to next 50 years, ii) projections which include uncertainties for the next period of 50-100 years, and iii) speculation for the period beyond 100 years.

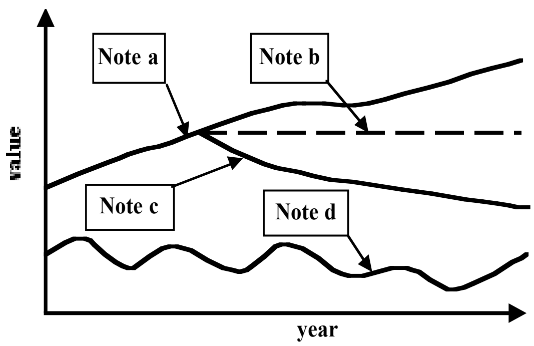

Figure 3. Possible behaviour/performance of component systems.

Notes:

a - Growth - population growth, growth of cities and other non-sustainable component systems, such as increase in soil salinity.

b - Stable conditions - sustainable systems such which balance input and output, balance availability of resources and demands or are component systems of distribution patterns (distribution patterns of rural areas in Australia and Poland [Soroczynski, 1999, 2001]).

c - Decline - sustainable and non-sustainable component systems; ***sustainable*** □ modified consumption eg. consumption of water per capita from water source when re-use of water has been introduced; ***non-sustainable*** □ annual output of fish, depletion of oxygen in water bodies and changes in water quality or lowering groundwater table due to excessive extraction.

d - Oscillation - climatic seasons or groundwater level of sustainable component systems.

Currently used and proposed time horizons for management of related systems are presented in Table 1. It is postulated that for a country or a region the adopted time horizon/s should be related to long-term population projections. The adoption of a time horizon longer than 50 years [ABS, 1996], say 100 years, could be an important step for the development of DSS and sustainable water systems for cities. Such an approach should provide new challenges for demographers, regional planners,

Table 1. Currently used and proposed time horizons for management of related systems.

SYSTEM	CURRENT	PROPOSED
• Environment	**• world, national, regional and projects** precautionary principle is being applied (Note 1)	**•world, national, regional and projects** precautionary principle implemented widely (Note 1)
• Climatic Conditions	**• world** forecasted conditions for 100 years **• national, regional and projects** forecasted conditions based on previous records	**• world** forecasted conditions for 100 years **• national, regional and projects** forecasted conditions based on climatic changes
• Population	**• world** 100 years or stable population **•national** 50 years **•regional-** 20-50 years	**• world** 100 years or stable population **•national** 100 years **•regional-** 20-100 years
• Land and Water Resources (including strategic planning for cities)	**•nationa-** 10-20 years **•regional and projects** 20-50 years	**• national and regional** 50-100 years or stable population **• projects** 20-50 years
• Economic Analyses	**• national, regional and projects** (Note 2)	**• national and regional** precautionary principle **• projects** (Note 2)

Notes:

1. O'Riordan. and Cameron [1994].
2. a) capital - term of a loan, b) operating costs - range of 25-100 years where applicable.

scientists, water resources planners and politicians. Further, it is postulated that the following two stages should be adopted for the development of appropriate strategies:

- an implementation stage of up to 50 years;
- an uncertain growth stage for next 50-100 years or to time at which it is considered that stable population will be reached.

The adoption of consistent time horizons for population growth and for management of natural resources including land and water resources would be a considerable step forward.

3. CONCLUSIONS

Integration of disciplines is possible by the application of ISA and on the basis of an integrated analysis of output and performance of component systems. For the purpose of this analysis behaviour of any component system should be analysed in a graphic form over time.

The issue of time horizons needs to be further debated. Due to the fact that different time horizons are used by different disciplines/systems but the adoption of an appropriate time horizon for DSS is an issue of great concern.

Due to complexity of issues and limitations of analytical tools such as computer models, scientific and expert interpretation needs to be elevated to a more important role in ISA and the development of DSS. ISA may be considered to be a "tool" for integrated modelling and assessment (IMA) which then provides inputs to DSS for appropriate management of sustainable development /sustainable systems. Further, sustainable development/sustainable systems need to be analysed on the basis of ISA and may be considered to be similar to large biological and chemical processing plants in which all processes need to be controlled.

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